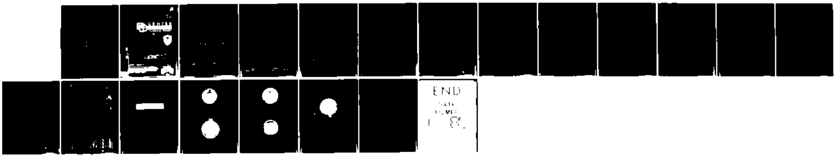
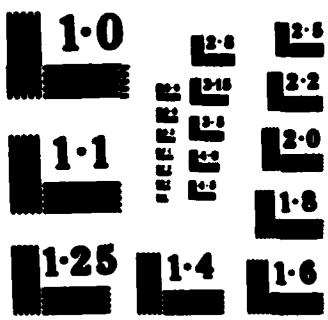
AD-A148 165   CRITICAL CRACK DEPTH IN T-142 TRACK PINS(U) ARMY   1/1
TANK-AUTOMOTIVE RESEARCH AND DEVELOPMENT COMMAND WARREN
MI T J KLER ET AL. OCT 84 TARADCOM-TR-13039

UNCLASSIFIED   F/G 20/11   NL




1·0
2·8
2·5
3·2
2·2
3·6
2·0
1·1
4·0
1·8
1·25
1·4
1·6

AD-A148 165

This report is not to be [illegible] position.

[illegible]

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for Public Release: Distribution Unlimited
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 13039	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION US Army Tank-Automotive Command 6b. OFFICE SYMBOL (If applicable) AMSTA-RCKM	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Warren, MI 48090	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Critical Crack Depth in T-142 Track Pins (Unclassified)

12. PERSONAL AUTHOR(S)
T.J. Kler, M.C. Padden, D.T. Ostberg

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM ____ TO ____	October 1984	22

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Fatigue life, Critical Crack Depth, T-142 Track Pins, Striations

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

1. The purpose of this investigation was to establish a crack depth-fatigue life relationship to aid in quality inspection parameters.

2. A limited number of T-142 track pins with similar residual stresses were cracked to a controlled depth and fatigued until failure.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL DONALD T. OSTBERG	22b. TELEPHONE (Include Area Code) (313) 574-5814 / 22c. OFFICE SYMBOL AMSTA-RCKM

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0. INTRODUCTION

The life of T-142 tank track pins is dependent on the location and extent of cracks in the pins. Cracks are introduced either through forming procedures or the application environment.

Procedures for detecting cracks range from established methods like magnetic particle inspection and ultrasonics to more developmental methods like acoustic emission testing. What has yet to be established in track pin crack detection is what the critical crack depth is, that is, what crack depth makes catastrophic failure imminent. We must also develop a means of life expectancy prediction. In other words, if a crack of certain depth and location is detected on a track pin, how much, if any, use remains?

2.0. OBJECTIVES

The purpose of this investigation is to correlate the remaining fatigue life in T-142 track pins with various crack depths and establish a critical crack depth. The method used was to initiate Stage I cracks in track pins through controlled methods and quantify the striation marks to Stage III, or final failure.

3.0. CONCLUSIONS

With the improved means of detecting crack defects in track pins, it is necessary to establish a crack depth-track pin life relationship. This testing shows that the fatigue life of track pins with cracks of a macroscopic scale (with respect to the induction hardened zone) is insignificant (i.e., cracks of a depth of .1 to 1 of the case depth thickness).

The means to initiate cracks of a specified depth are theoretical so the actual crack depth could not be accurately verified. The actual depth of the initial cracks could only be checked by assuming that the chordal length of the crack was in fact linear, which may or may not have been the case.

4.0. RECOMMENDATIONS

A larger number of track pins should be tested in a similar manner to get a data base to establish between the crack depth and track pin life.

5.0. DISCUSSION

5.1. Test Pins.

The six pins tested were verified for similarity. (See Addendum). The pin's residual stresses were verified by X-ray diffraction methods as outlined by Catalano & Allen in "Track Pin Induced Stresses," Report Number 12407. The compressive residual stresses due to shot peening were:

TABLE 5-1. Residual Stress in Test Pins

Pin #	Longitudinal Stress (Kpsi)	Hoop Stress (Kpsi)
1	55	54
2	65	63
3	71	69
4	69	71
5	63	75
6	64	62

Accuracy to ± 5 Kpsi

Magnetic particle inspection of pins revealed similar surfaces with no detectable microfissures.

5.2. Fatigue Life of Cracked Pins

The technique used to put a predetermined crack depth into the individual pins was achieved by loading the pins in a three-point bend fatigue configuration. With the stroke limit set to terminate loading at a predetermined limit (which would indicate a crack development) a different size crack could be put into the pins for each stroke limit setting.

With cracks of various depths established, the pins were fatigued at a lesser load and cycled to failure.

Results of the pins tested:

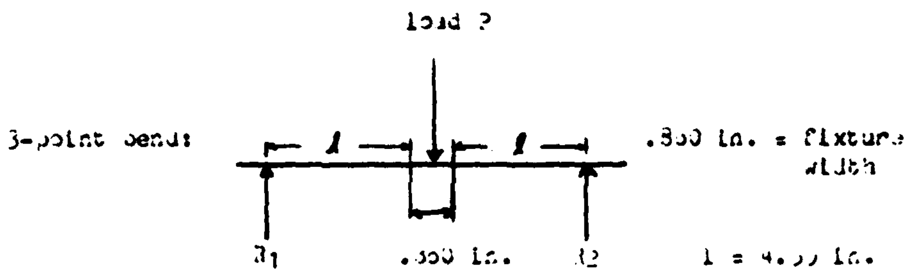
TABLE 5-2. Fatigue Life with Induced Cracks

Pin #	Calculated Crack Depth	Cycles to Failure
1	.003 in.	4,000
2	.006 in.	10,200
3	.006 in.	5,000
4	.009 in.	5,000
5	.100 in.	3,000
6	Failed in induced crack fatigue load	

As can be seen from the crack depth-cycles to failure values obtained, the limited number of pins tested make it impossible to correlate the values, but the results indicate that a crack within the induction hardened zone will effectively have a life span similar to a pin cracked through the hardened zone. Examination of the pin's fracture faces using electron microscopy revealed similar, but nonquantifiable, striation patterns. In metals with hardnesses greater than R_c50, the fatigue striations are not well defined and are not accurately quantified. Such is the case with the hardened zone of the track pins.

5.3. Theoretical Development of Controlled Crack Propagation

The theoretical development of a controlled crack depth and the application was carried out by Professor J. Wallace and Joseph Snyder of Case Western University, Cleveland, Ohio. Through correlating the section modulus with the new cross-sectional area, due to an induced crack, an iterative method is used with the emperical formulation to yield the desired effective cross-sectional area.

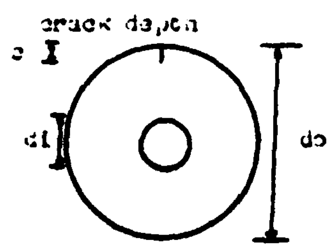


with an applied load of P:

bending moment, $M = l\,\frac{P}{2}$

section modulus, $S = I/C$

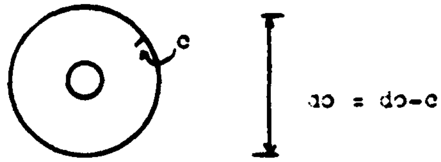
$$S = \frac{lP}{4}\;\frac{64\,do}{(do^4-di^4)}$$



a crack of length c ➔ $S = 1$

Moment of inertia when a crack exists using parallel axis theorem:

$$I = I_c + Ad_1^2$$



$$I = \frac{\pi}{64} d_o^4 - \left(\frac{\pi d_i^2}{64} + \frac{\pi d_i^2}{4} \left(\frac{c^2}{2}\right) \right)$$

$$= \frac{\pi}{64} \left((d_o - c)^4 - d_i^4 - 4 d_i^2 c^2\right)$$

Generalized section modulus:

$$S = I/C = \frac{\pi}{32} \frac{((D_o - c)^4 - d_i^4 - 4 d_i^2 c^2)}{(d_o - c)}$$

Stress at the crack tip is:

$$= \frac{16\ lP\ (d_o - c)}{((d_o - c)^4 - d_i^4 - 4 d_i^2 c^2)\pi}$$

Maximum deflection:

$$= \frac{Pl}{48EI} (3L^2 - 4l^2)$$

$E = 29 \times 10^6$ psi
$L = 10"$
$l = 4.57"$

Assuming failure in approximately 10,000 cycles in a load range of 210 Kpsi:

$$P = \frac{210{,}000\ (4)\ (\ )\ (1.249^4 - .500^4)}{4.59\ (64)\ (1.249)}$$

$$= 17{,}054 \text{ lb } 17{,}000 \text{ lb}$$

$$S = \frac{17{,}000\ (4.59)\ (64)\ (1.249)}{4\ \ (1.249^4 - .5^4)}$$

$$= 209.350 \text{ psi}$$

$$\delta_{BAR} = \frac{17{,}000\ (4.59)\ 64\ (3\ (100) - 4(4.59)^2)}{48\ (29{,}013{,}600)\ (\ )\ (1.249^4 - .5)^4)}$$

$$= .104"$$

$$\Delta \delta_c = \frac{17{,}000\ (4.59)\ 64\ (300 - 4(4.59)^2)}{48\ (29{,}013{,}600)\ \ ((d_o - c)^4 - d_i^4 - 4 d_i^2 c^2)}$$

$$= \frac{.240377}{((1.249 - c)^4 - .5^4 - 4(.5)^2 c^2)}$$

Now the deflection can be correlated with the desired crack depth, c.

A load of 17,000 lbs was applied to the pins. The center support spanned .859 in. and the reaction supports were 5 in. apart from the center. This produces a maximum stress of 209 KSI in the outer surface of the bar. The load range was from 400 lb to 17,000 lb at a frequency of 10 Hz. By monitoring the deflection of a pin during the fatigue testing, the development of a crack can be detected. With the stroke controls of the fatigue testing machine set to terminate testing at a specified deflection, a crack of a calculated depth is obtained. Table 5-3 summarizes the results of the induced cracks and the cycles to failure at the lesser load.

Figure 5-1 shows the number six track pin which failed at the edge of the center load fixture at 17,210 cycles.

5.4. Fatigue Testing to Failure

Fatigue testing to failure for the remaining five track pins was carried out on a similar three-point test fixture but the reaction centerlines were spaced 19 inches apart. The applied load was 3,000 ± 2,900 lbs at a frequency of 10 Hz. Figures 5-2, 5-3 & 5-4 show the fracture faces of the test pins. There is no distinction between Stage I and Stage II fatigue transition.

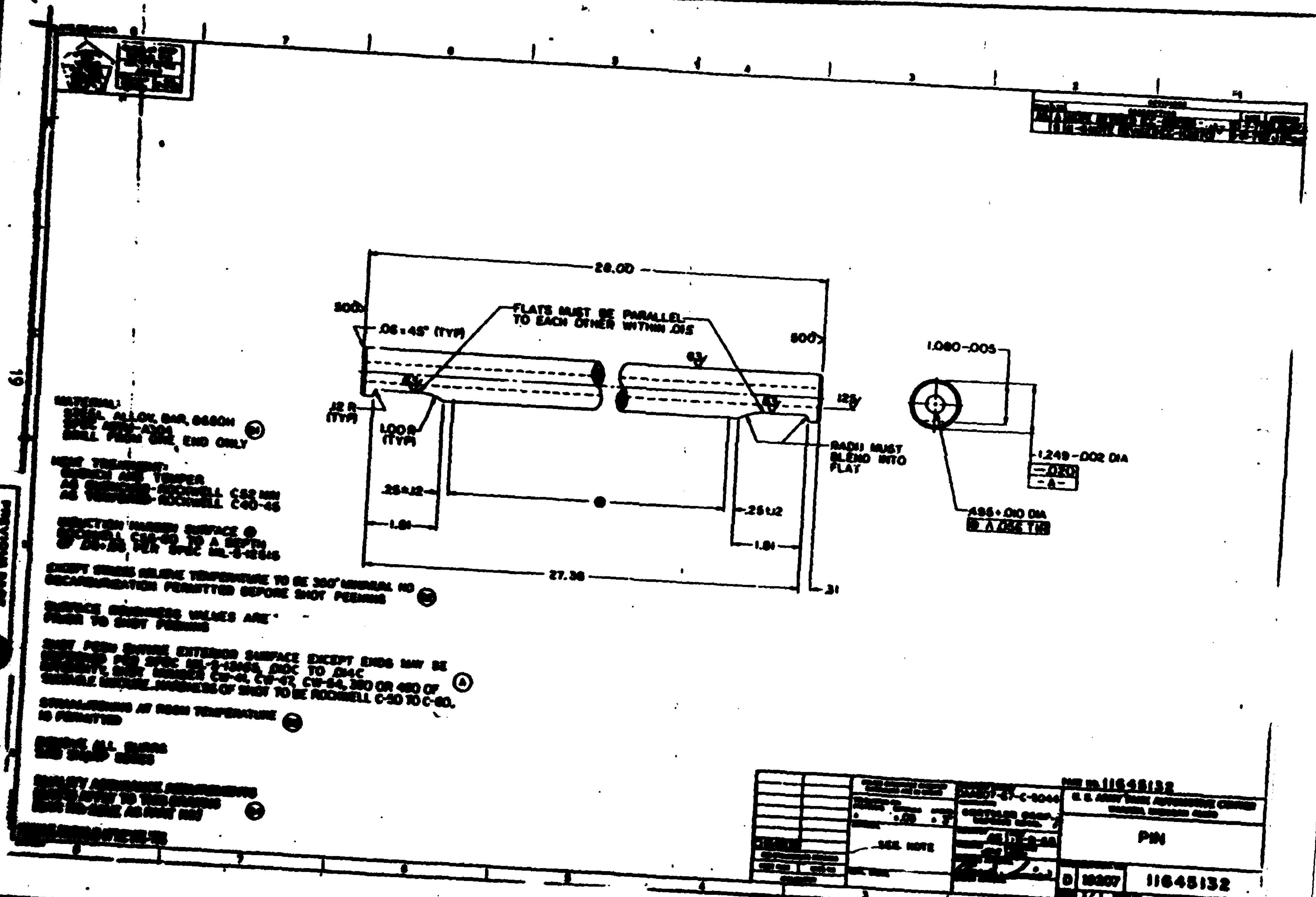
TABLE 5-3. Track Pin Test Data

Pin	Residual Stress longitudinal Kpsi	Residual Stress hoop Kpsi	Estimates from calculations crack length	Number of cycles	Change in deflection	Number of cycles to failure
1	58	64	.203 in.	14,100	.001 in.	4,000
2	65	63	.006 in.	20,000	.002 in.	102,000
3	71	59	.009 in.	35,650	.003 in.	5,000
4	69	71	.005 in.	26,350	.002 in.	5,000
5	68	70	.100 in.	26,390	.045 in.	5,000
6	64	62	failed	17,210	.030 in.	

ADDENDUM

(Track Pin Specifications)

Encl 1



PREVIOUS PAGE IS BLANK

Figure 5-1. Track pin 6.

Figure 5-2. Fracture face of track pin 1.

Figure 5-3. Fracture face of track pin 2.

Figure 5-4. Fracture face of track 3.

Figure 5-5. Fracture face of track pin 4.

Figure 5-6. Fracture face of track pin 5.

DISTRIBUTION LIST

	Copies
Commander US Army Tank-Automotive Command ATTN: AMSTA-RCKI Warren, MI 48090	12
Commander US Army Tank-Automotive Command ATTN: AMSTA-TSL, Technical Library Warren, MI 48090	2
Commander Defense Technical Information Center Bldg 5, Cameron Street (ATTN: DDAC) 5010 Duke Street Alexandria, VA 22314	15
Case Western University Department of Metallurgical & Materials Science ATTN: Prof. John Wallace 10900 Euclid Avenue Cleveland, OH 44106	2
Manager Defense Logistics Studies Information Exchange ATTN: DRXMC-D Fort Lee, VA 23801	2